

WHAT IS CLAIMED IS:

1. An apparatus for modifying the concentration of a predetermined substance present in a first fluid flowing through a conduit having an inner surface, the apparatus comprising:

a first hollow fiber membrane module including:

a plurality of elongated hollow fiber membranes located generally in adjacent, parallel relationship to each other, wherein each of the hollow fiber membranes includes a generally cylindrical wall defining an interior surface and an exterior surface, and further defining a first end and a second end, wherein each of the cylindrical walls is configured to transmit the predetermined substance therethrough, between its interior surface and its exterior surface, and

a module housing that supports the plurality of elongated hollow fiber membranes with their first ends arranged in adjacent relationship and with their second ends arranged in adjacent relationship, wherein a transverse flow path is defined past the exterior surfaces of the hollow fiber membranes,

wherein the first hollow fiber membrane module is configured to be positionable within the conduit and further to be matable with a similarly configured hollow fiber membrane module;

a baffle assembly located within the conduit and configured to direct the flow of the first fluid through the first hollow fiber membrane module, along the transverse flow path past the exterior surfaces of the plurality of elongated hollow fiber membranes; and

a fluid source that directs a second fluid to flow through the plurality of elongated hollow fiber membranes, from their first ends to their second ends;

whereby the predetermined substance is transmitted through the cylindrical walls of the plurality of elongated hollow fiber membranes, to modify the concentration of the predetermined substance in the first fluid.

2. The apparatus according to claim 1, wherein:

the apparatus further comprises a second hollow fiber membrane module substantially similar to the first hollow fiber membrane module and located within the conduit, adjacent to the first hollow fiber membrane module;

the fluid source further directs the second fluid to flow through the plurality of elongated hollow fiber membranes of the second hollow fiber membrane module, from their first ends to their second ends; and

the baffle assembly further is configured to direct the first fluid, to flow first through the first hollow fiber membrane module and then through the second hollow fiber

- 10 membrane module, along the transverse flow path past the exterior surfaces of the plurality of elongated hollow fiber membranes of the second hollow fiber membrane module.
3. The apparatus according to claim 1, wherein the hollow fiber membranes are made of a material selected from the group comprising polypropylene, polyvinylidene fluoride, and Teflon®.
4. The apparatus according to claim 1, wherein the conduit is a cylindrical pipe.]
5. The apparatus according to claim 1, wherein the module housing comprises:
a first membrane housing located adjacent to the first ends of the hollow fiber membranes that is coupled to the first ends of the hollow fiber membranes;
a first end plate located adjacent to the first ends of the hollow fiber membranes
5 and connected to the first membrane housing;
a second membrane housing located adjacent to the second ends of the hollow fiber membranes that is coupled to the second ends of the hollow fiber membranes;
a second end plate located adjacent to the second ends of the hollow fiber
10 membranes and connected to the second membrane housing; and
a first side support connected between the first membrane housing and the second membrane housing that maintains a position of the first membrane housing relative to the second membrane housing.
6. The apparatus according to claim 5, further comprising a second side support connected between the first membrane housing and the second membrane housing.
7. The apparatus according to claim 5, further comprising a material that fills spaces between the first ends of the hollow fiber membranes, couples the first ends of the hollow fiber membranes to the first membrane housing, fills other spaces between the second ends of the hollow fiber membranes, and couples the second ends of the hollow fiber membranes to the
5 second membrane housing.
8. The apparatus according to claim 7, wherein the material is selected from the group comprising epoxy, silicon, and urethane.

9. The apparatus according to claim 5, further comprising:

a first O-ring positioned between the first membrane housing and the first end plate before the first end plate is secured to the first membrane housing that provides a first seal between the first membrane housing and the first end plate; and

5 a second O-ring positioned between the second membrane housing and the second end plate before the second end plate is secured to the second membrane housing that provides a second seal between the second membrane housing and the second end plate.

10. The apparatus according to claim 5, further comprising:

a first tube fitting connected to the first end plate; and

a second tube fitting connected to the second end plate.

11. The apparatus according to claim 5, further comprising a flow divider connected to the first membrane housing that directs the flow of the first fluid after the first fluid flows past the hollow fiber membranes.

12. The apparatus according to claim 11, wherein the flow divider includes a plurality of flow vanes.

13. The apparatus according to claim 11, further comprising a module guide connected to the flow divider.

14. The apparatus according to claim 13, further comprising a module guide runner connected to the module guide.

15. The apparatus according to claim 13, wherein:
the conduit includes a rib connected to the inner surface; and
the module guide interfaces with the rib.

16. The apparatus according to claim 5, wherein the baffle assembly comprises:
an input flow diversion assembly located adjacent to the first hollow fiber
membrane module and configured to direct the flow of the first fluid into the first hollow fiber
membrane module; and
- 5 an output flow diversion assembly located adjacent to the first hollow fiber
membrane module, with the first hollow fiber membrane module located between the input flow
diversion assembly and the output flow diversion assembly, wherein the output flow diversion
assembly is configured to direct the flow of the first fluid leaving the first hollow fiber membrane
module.
17. The apparatus according to claim 16, wherein:
the input flow diversion assembly includes an upper portion;
the output flow diversion assembly includes a lower portion; and
both the upper portion and the lower portion are designed to interface with the
- 5 inner surface of the conduit.
18. The apparatus according to claim 16, wherein the first hollow fiber membrane
module further includes a flow divider connected to the first membrane housing that directs the
flow of the first fluid after the first fluid flows past the hollow fiber membranes.
19. The apparatus according to claim 18, further comprising a module guide
connected to the flow divider.
20. The apparatus according to claim 19, wherein:
the conduit includes a rib connected to its inner surface; and
the module guide interfaces with the rib.
21. An apparatus for modifying the concentration of a predetermined substance
present in a first fluid flowing through a conduit having an inner surface, the apparatus
comprising:
- 5 a first stage and an adjacent second stage through which the first fluid flows,
wherein each of the first stage and the second stage includes a hollow fiber membrane module
including:
a plurality of elongated hollow fiber membranes located generally
in adjacent, parallel relationship to each other, wherein each of the hollow fiber

10 membranes includes a generally cylindrical wall defining an interior surface and
an exterior surface, and further defining a first end and a second end, wherein each
of the cylindrical walls is configured to transmit the predetermined substance
therethrough, between its interior surface and its exterior surface, and
a module housing that supports the plurality of elongated hollow
fiber membranes with their first ends arranged in adjacent relationship and with
15 their second ends arranged in adjacent relationship, wherein a transverse flow path
is defined past the exterior surfaces of the hollow fiber membranes,
wherein the hollow fiber membrane module is configured to be
positionable within the conduit and further to be matable with a similarly
configured hollow fiber membrane module;
20 a first flow diversion assembly located within the conduit between the first and
second stages and configured to direct the flow of the first fluid into the first stage and direct the
flow of the first fluid leaving the second stage;
a second flow diversion assembly located within the conduit adjacent to the first
stage, with the first stage located between the first flow diversion assembly and the second flow
25 diversion assembly, wherein the second flow diversion assembly is configured to direct the flow
of the first fluid leaving the first stage; and
a third flow diversion assembly located within the conduit and adjacent to the
second stage, with the second stage located between the first flow diversion assembly and the
third diversion assembly, wherein the third flow diversion assembly is configured to direct the
30 flow of the first fluid into the second stage; and
a fluid source that directs a second fluid to flow through the plurality of elongated
hollow fiber membranes, from their first ends to their second ends;
whereby the predetermined substance is transmitted through the cylindrical walls
of the plurality of elongated hollow fiber membranes, to modify the concentration of the
35 predetermined substance in the first fluid as the first fluid flows past the exterior surfaces of the
plurality of elongated hollow fiber membranes.

22. The apparatus according to claim 21, wherein:
the first flow diversion assembly includes an upper portion;
each of the second flow diversion assembly and the third flow diversion assembly
includes a lower portion; and
5 the upper portion and the lower portions are designed to interface with the inner
surface of the conduit.

23. The apparatus according to claim 21, further comprising a module guide connected to the hollow fiber membrane module in each of the first stage and the second stage.

24. The apparatus according to claim 23, wherein:
the conduit includes a rib connected to the inner surface; and
the module guide interfaces with the rib.

25. An apparatus for modifying the concentration of a predetermined substance present in a first fluid flowing through a conduit having an inner surface, the apparatus comprising:

a plurality of hollow fiber membrane modules configured to be placed in a contiguous relationship within the conduit, wherein each hollow fiber module includes:

a plurality of elongated hollow fiber membranes located generally in adjacent, parallel relationship to each other, wherein each of the hollow fiber membranes includes a generally cylindrical wall defining an interior surface and an exterior surface, and further defining a first end and a second end, wherein each of the cylindrical walls is configured to transmit the predetermined substance therethrough, between its interior surface and its exterior surface, and

a module housing that supports the plurality of elongated hollow fiber membranes with their first ends arranged in adjacent relationship and with their second ends arranged in adjacent relationship, wherein a transverse flow path is defined past the exterior surfaces of the hollow fiber membranes,

wherein the first hollow fiber membrane module is configured to be positionable within the conduit and further to be matable with a similarly configured hollow fiber membrane module;

a baffle assembly located within the conduit and configured to direct the flow of the first fluid through each hollow fiber membrane module, along the transverse flow path past the exterior surfaces of the plurality of elongated hollow fiber membranes; and

a fluid source that directs a second fluid to flow through the plurality of elongated hollow fiber membranes, from their first ends to their second ends;

whereby the predetermined substance is transmitted through the cylindrical walls of the plurality of elongated hollow fiber membranes, to modify the concentration of the predetermined substance in the first fluid.

26. The apparatus according to claim 25, wherein one hollow fiber membrane module of the plurality of hollow fiber membrane modules further includes a flow divider connected to the one hollow fiber membrane module that directs the flow of the first fluid after the first fluid flows past the hollow fiber membranes of the one hollow fiber membrane module.

27. The apparatus according to claim 25, further comprising:

a first flow diversion assembly located adjacent to the plurality of hollow fiber membrane modules and configured to direct the flow of the first fluid into the plurality of hollow fiber membrane modules; and

5 a second flow diversion assembly located adjacent to the plurality of hollow fiber membrane modules, with the plurality of hollow fiber membrane modules located between the first flow diversion assembly and the second flow diversion assembly, wherein the second flow diversion assembly is configured to direct the flow of the first fluid leaving the plurality of hollow fiber membrane modules.

28. A method for fabricating a hollow fiber membrane module used in a conduit, the method comprising:

providing a plurality of elongated hollow fiber membranes wherein:

hollow fiber membranes included in the plurality of elongated

5 hollow fiber membranes are located adjacent to one another, and

each of the hollow fiber membranes includes a first end and a second end;

providing a first membrane housing configured to be coupled to the first ends of the hollow fiber membrane;

10 providing a first end plate configured to be connected to the first membrane housing;

providing a second membrane housing configured to be coupled to the second ends of the hollow fiber membranes;

15 providing a first side support configured to be connected between the first membrane housing and the second membrane housing;

providing a second end plate configured to be connected to the second membrane housing;

providing a material configured to fill spaces between the first ends of the hollow fiber membranes, couple the first ends of the hollow fiber membranes to the first membrane